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AUTHOR Aikenhead, Glen S.
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ABSTRACT

Science teachers have been encouraged to teach "authentic science" instead of the false and mythical images of ideal science most often found in science textbooks. To help teachers in this task information is provided on conditions for learning and on how to evaluate student responses to statements which focus on the nature of the scientific enterprise. A sample is offered which includes: (1) a situation (or statement) presented to students; (2) a question asking students to agree or disagree with the ideas conveyed; and (3) typical student responses, each accompanied by an evaluative comment and suggested numerical score. Explanations for the numerical scores are included. (JN)

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Research Matters... To the Science Teacher

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TEACHING AUTHENTIC SCIENCE

By Glen S. Aikenhead

With the pressure to teach **authentic** science instead of ideal science, what can a science teacher do? Investigations of students' views on the scientific enterprise have explored the following questions:

(1) What conditions are necessary for successful learning?
(2) How can a teacher evaluate student views?

It is extremely important for a teacher to acquire reliable feedback about his or her own teaching.

Conditions for Learning

Seldom do students pick up authentic images about science from the subtle comments or elements within a science course. Rather, the ideas about the **scientific enterprise** (its characteristics and limitations) must be the **center of attention**. Two examples will illustrate this point.

(1) If a particular lab is intended to convey that **human imagination** is involved in scientific model building (e.g., the "black box" lab), then students must be asked in the lab to address the role of human imagination, they must discuss it, and they must find it part of their evaluation in the course.

(2) If your objective is to teach the distinction between **science** (the process of understanding natural phenomena) and **technology** (the process of designing techniques and implements to respond to human needs), then projects and problems must be presented to help students distinguish between science and technology.

Students will come to class with their naive ideas about the scientific enterprise—often the conception of ideal science or scientism. These ideals or mythical notions must be challenged before authentic images can be learned. Simulations, projects, reading assignments, field trips, forums, debates and especially discussions are all appropriate teaching strategies to help them **relearn** or **reformulate** their views of science.

Most importantly, the teacher must realize that it usually takes a long time and considerable evidence for students to change their ideas about the nature of science. It may take a full year for students to realize that well-known scientific laws are not truths found in nature, but are man-made generalizations. It may take three years before your students develop an accurate view of the methods of authentic science.

On the other hand, ideas which are new or relatively unfamiliar to students are quickly learned. Ideas such as recognizing that the scientific enterprise is comprised of public AND private science, each employing its own set of values, may be easily assimilated by students. Similarly, students are generally amenable to learning about the social and political contexts of science.

Teachers find that activities which focus on the nature of the scientific enterprise should be introduced early in a course, thus allowing for reinforcement of these ideas during the whole course. Reasonable time taken for such activities does not adversely affect student achievement on traditional science content.

How to Evaluate Student Responses

Objectively-scored types of questions do offer objectivity of scoring from the teacher's point of view, but the questions are woefully inadequate in assessing student beliefs. The students' interpretations, however, are clearly evident in their written responses. Student paragraphs, typically two to five sentences in length, are more clearly written when:

(1) students are presented with a situation or statement; then
(2) asked whether they agree, disagree or can't tell; and then
(3) asked to explain the reasons for their choice.

This second point is important because it requires the student to take a position from which to argue. Students will often change their initial choice as they write their explanation. Somewhat surprisingly similar paragraphs will be written for opposite initial positions. (See the example below).

Teachers trained in science are not comfortable or confident in grading student writing. Here are some guidelines aimed at removing this obstacle. First,

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familiarize yourself with a range of answers by reading a few responses anticipated to be good and poor. Assign three points to answers that deal with the topic in a sophisticated way, given the nature of the instructional activity and the maturity level of your class. Two different explanations may each receive three marks, as long as they are logically constructed. Seldom is an answer considered right or wrong; but is analyzed as a better or poorer response.

Zero points are assigned to poor or uniformed responses, while one or two points are awarded to more informed responses--those that reflect some degree of realistic understanding. Three points are awarded to answers that are clear, precise and logical. (See the example below). It is very helpful to compose a scoring scheme for each individual question.

Students usually need practice in writing paragraphs about the scientific enterprise. Homework and quizzes are useful places for this to begin. Students who are shy about writing need individual attention and encouragement. English and social studies colleagues may have suggestions for motivating students, as well as comments about scoring schemes and efficient use of marking time.

Writing paragraph responses requires student time during a test and teacher time for evaluating. Teachers who value the assessment of student beliefs will find the time to do so. The speed of scoring increases with practice. Here are some useful time-saving strategies:

(1) Use only a small number of questions that require writing per test (one to four per test hour). This is helpful even though they might not cover the full range of content you are interested in.
(2) Use the format suggested above so you can recognize common student arguments and thus score a paragaraph very quickly.

An Example

Situation In an average 10th grade class, a discussion had taken place about whether the photoghraphs in a science text had more to do with **technology** (responding to human needs) than with **science** (finding out about nature).

Question Ken was showing a friend the new car he had bought. "Look at its polyplastic coating, the windshield changes tint with the brightness of the sun, and its computer fuel injection system! What will those scientists think of next!"

Do you agree or disagree with Ken's feelings about scientists? Give a reason for your opinion (in a short paragraph).

Student Response	Evaluation Comment	Suggested Score
1. I agree. All those things get people to buy bigger cars and that wastes gas. Scientists should think about those things before they make them.	Irrelevant to the statement.	0
2. I disagree. Scientists don't know ahead of time what they'll come up with. They do their research to find new knowledge.	True, but does not relate explicitly with the statement.	0 or 1
3. I disagree. This is only one kind of science, making things for people to use. Science is mostly discovering things like theories. Then someone else uses the discoveries to make things for people to use.	The distinction between science and technology is made, but not labelled. The 2nd and 4th sentences are contradicatory.	1 or 2
4. Disagree. The car manufacturer makes these things, not the scientist.	The distinction between science and technology is made, but the role of the scientist is not clear.	0
5. I disagree. The technologist will have to think of what comes next. He gets his ideas from the scientist. He applies them to make things for people to use.	The distinction is clear and the answer relates to the statement.	3
6. I agree, except you have to remember that its not the scientist who actually makes this stuff. He comes up with the theories and laws. It's the technologist who puts those ideas to work.	Ditto.	3

Note that the best responses above would be scored lower in another situation; for instance, 12th grade students who had studied how science is as much technology-driven as technology is science-driven. The better responses above address a distinction between science and technology.

The National Association For Research in Science Teaching is an organization that seeks to improve science teaching through research. For further information, contact the NARST Executive Secretary:
Dr. Glenn Markle
401 Teacher College
University of Cincinnati
Cincinnati, Ohio 45221

For further information about this research area, please contact Dr. Glen S. Aikenhead at:
College of Education
University of Saskatchewan
Saskatoon, Saskatchewan, Canada S7N 0W0